

HIGH TEMPERATURE DIE CASTING APPARATUS AND METHOD THEREFOR

BACKGROUND

5 This disclosure relates to die casting and, more specifically, a die casting system that has the ability to operate at high temperatures.

 In general, die casting is a process that includes moving molten metal into a die cavity to form a desired shape. The process typically includes transporting the molten metal into the die cavity, holding the metal in the cavity for a period of time
10 until the casting solidifies, removing the casting from the die cavity, and trimming the casting to remove any scrap.

SUMMARY

 A disclosed high temperature die casting system includes a die casting tool
15 that has dies that are adapted for forming a component. Due to the nature of the process, the die casting tool is operable to heat and maintain a temperature of the dies above 500°F/260°C. At least a portion of the die casting tool that is exposed for contact with molten die casting material has a substrate and barrier coating on the substrate to protect from the molten die casting material.

20 In another aspect, a high temperature die casting system includes a die casting tool having a substrate and a barrier coating on the substrate. The barrier coating is a material selected from partially or fully stabilized zirconia, titanium nitride, tungsten carbide, silicon carbide, silicon nitride, titanium carbide, silicon-oxygen-aluminum-nitrogen, hafnium carbide, zirconium carbide, and combinations thereof.

25 An exemplary method for a high temperature die casting system includes maintaining a die casting tool having dies that are adapted for forming a component at a temperature above 500°F/260°C, and using a barrier coating on at least a portion of the die casting tool that is exposed for contact with molten die casting material to protect the underlying substrate of the die casting tool from contact with the molten
30 die casting material.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of the disclosed examples will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

5 Figure 1 illustrates an example die casting system.

Figure 2 illustrates an example die casting tool having a barrier coating.

Figure 3 illustrates another example die casting tool having a barrier coating and a bond coat.

10 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates a die casting system 10 including a reusable die 12 having a plurality of die elements 14, 16 that function to cast a component 15. The component 15 could include aeronautical components, such as a gas turbine engine blade or vane, or non-aeronautical components. Although two die elements 14, 16 are depicted by Figure 1, it should be understood that the die 12 could include more or
15 fewer die elements, as well as other parts and other configurations.

The die 12 is assembled by positioning the die elements 14, 16 together and holding the die elements 14, 16 at a desired position via a mechanism 18. The mechanism 18 could include a clamping mechanism of appropriate hydraulic, pneumatic, electromechanical, and/or other configurations. The mechanism 18 also
20 separates the die elements 14, 16 subsequent to casting.

The die elements 14, 16 include internal surfaces that cooperate to define a die cavity 20. The die elements 14, 16 may additionally include one or more heating elements 17 for heating and maintaining the die cavity 20 at a desired temperature above 500°F/260°C. For instance, the heating elements may heat the die elements 14, 16 up to 500°F/260°C during initial start-up of the die elements 14, 16, maintain the desired temperature during operation of the die elements 14, 16, and maintain the desired temperature during thermal cycling as components are produced in the die casting system 10. The heating elements 17 may be resistance heaters, induction
25 heaters, a recirculating thermal medium, such as, but not limited to hot oil, or combinations of different kinds of heaters that are operable to heat the die cavity 20 to the desired temperature and then maintain that temperature (e.g., via non-application of heat or in combination with a cooling element). Traditional casting dies are not
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commonly equipped to specifically heat the cavity and may be present in the system for the purpose of removing excess heat from the die. The elevated temperature of die elements 14, 16 serves to reduce the temperature differential between the die elements and the molten die casting material to reduce heat checking.

5 A shot tube 24 is in fluid communication with the die cavity 20 via one or more ports 26 that extend into the die element 14, the die element 16 or both. A shot tube plunger 28 is received within the shot tube 24 and is moveable between a retracted and injected position (in the direction of arrow A) within the shot tube 24 by a mechanism 30. A shaft 31 extends between the mechanism 30 and the shot tube
10 plunger 28. The mechanism 30 could include a hydraulic assembly or other suitable system, including, but not limited to, pneumatic, electromechanical, hydraulic or any combination of systems.

 The shot tube 24 is positioned to receive a charge of material from a melting unit 32, such as a crucible, for example. The melting unit 32 may utilize any known
15 technique for melting an ingot of metallic material to prepare molten metal for delivery to the shot tube 24, such as will be further discussed below. In this example, the charge of material is melted into molten metal by the melting unit 32 at a location that is separate from the shot tube 24 and the die 12. However, other melting configurations are contemplated as within the scope of this disclosure. The example
20 melting unit 32 is positioned in relative close proximity to the die casting system 10 to reduce the transfer distance of the charge of material between the melting unit 32 and the die casting system 10.

 Materials used to die cast a component 15 with the die casting system 10 include, but are not limited to, nickel-based super alloys, cobalt-based super alloys,
25 titanium alloys, high temperature aluminum alloys, copper-based alloys, iron alloys, molybdenum, tungsten, niobium or other refractory metals. This disclosure is not limited to the disclosed alloys, and other high melting temperature materials may be utilized to die cast a component 15. As used in this disclosure, the term “high melting temperature material” is intended to include materials having a melting temperature of
30 approximately 1500°F/815°C and higher.

 The charge of material is transferred from the melting unit 32 to the die casting system 10. For example, the charge of material may be poured into a pour hole 33 of the shot tube 24. A sufficient amount of molten metal is poured into the

shot tube to fill the die cavity 20. The shot tube plunger 28 is actuated to inject the charge of material under pressure from the shot tube 24 into the die cavity 20 to cast the component 15. Although the casting of a single component is depicted, the die casting system 10 could be configured to cast multiple components in a single shot.

5 Although not necessary for all materials, at least a part of the die casting system 10 can be positioned within a vacuum chamber 34 that includes a vacuum source 35. A vacuum is applied in the vacuum chamber 34 via the vacuum source 35 to render a vacuum die casting process. The vacuum chamber 34 provides a non-reactive environment for the die casting system 10 that reduces reaction,
10 contamination or other conditions that could detrimentally affect the quality of the die cast component, such as gas entrapment or the formation of oxides or nitrides within the die cast component that can occur from exposure to atmospheric gasses. In one example, the vacuum chamber 34 is maintained at a pressure between 1×10^{-3} Torr and 1×10^{-4} Torr, although other pressures are contemplated. The actual pressure of
15 the vacuum chamber 34 will vary based upon the type of component 15 or alloy being cast, among other conditions and factors. In the illustrated example, each of the melting unit 32, the shot tube 24 and the die 12 are positioned within the vacuum chamber 34 during the die casting process such that the melting, injecting and solidifying of the high melting temperature material are all performed under vacuum.
20 In another example, the chamber 34 is backfilled with an inert gas, such as Argon, for example.

 The example die casting system 10 of Figure 1 is illustrative only and could include more or fewer sections, parts and/or components. This disclosure extends to all forms of die casting, including but not limited to, horizontal, inclined, or vertical
25 die casting systems and other die casting configurations.

 At casting temperatures that exceed $1500^{\circ}\text{F}/815^{\circ}\text{C}$, traditional die casting tools rapidly wear out from heat checking and thermal fatigue. The wear is even more evident at higher casting temperatures of metals or metal alloys that have melting points above $2500^{\circ}\text{F}/1371^{\circ}\text{C}$. The rapid wear renders traditional tooling unsuitable
30 for high temperature die casting. In this regard, as will be explained in more detail below, the die casting system 10 utilizes a barrier coating 40 that protects the die casting system 10 from the effects of the high temperature molten die casting material.

High temperature differentials between a molten die casting material and walls of the die casting tooling can cause heat checking and reduce tool life. In the example, the die casting system 10 includes the barrier coating 40 on at least a portion of the tool surfaces that are exposed for contact with the molten die casting material, to alleviate heat checking or other influences of the high temperature die casting material. In general, any of the components of the die casting system 10 that has a surface that contacts the molten metal is considered to be a die casting tool or component. As an example, the surfaces of the die cavity 20, shot tube 24, shot tube plunger 28, melting unit 32, pour hole 33, and any runners or gates may include the barrier coating 40.

Figure 2 illustrates a selected portion of one such area that includes the barrier coating 40 on a substrate 42 of a given die casting tool. In this example, the barrier coating 40 is deposited directly onto the surface of the substrate 42. The substrate 42 may be any suitable material for the given component. As an example, the substrate 42 may be a superalloy, such as a nickel and/or cobalt alloy. It is to be understood, however, that the material of the substrate 42 is not limited to any particular composition and one of ordinary skill in the art would be able to recognize suitable materials to meet their particular needs.

The barrier coating 40 forms a thermal barrier between the molten die casting material and the underlying substrate 42. In that regard, the material of the barrier coating 40 has a relatively high thermal resistance. For instance, the barrier coating 40 may be a ceramic material, such as an oxide, a nitride, a carbide, a zirconia material, a gadolinia material or combinations thereof.

The oxide may be a combination of several different oxides, including at least one oxide and the balance comprising a first oxide. The first oxide may be selected from the group consisting of zirconia, ceria, and hafnia. The at least one oxide may have a formula A_2O_3 , where A is selected from the group consisting of La, Pr, Nd, Sm, Eu, Th, In, Sc, Y, Dy, Ho, Er, Tm, Yb, Lu, and mixtures thereof.

The carbide may be a refractory metal carbide, such as a carbide of tungsten, niobium, tantalum, rhenium, or molybdenum. Additional carbide materials include silicon, titanium, hafnium, zirconium, or combinations thereof. In some examples, the barrier coating 40 is a partially or fully stabilized zirconia, titanium nitride, silicon nitride, a silicon-aluminum-oxy-nitride (SiAlON), boron nitride, aluminum nitride,

alumina (e.g., alpha-alumina), or any combination thereof. In embodiments, the barrier coating 40 is gadolinia and zirconia and may include 5-50 mol% gadolinia. The gadolinia and zirconia may include fluorite and a pyrochlore structure.

Alternatively, or in addition to any other materials for the barrier coating 40, the barrier coating 40 may be or may include a metallic coating. The metallic coating may be a platinum group metal, such as ruthenium, rhodium, palladium, osmium, iridium, and platinum. In other embodiments, the metallic coating may be a nickel alloy. For instance, the nickel alloy may consist essentially of up to 15 wt% cobalt, 5-18 wt% chromium, 7.5-12 wt% aluminum, 0.1-1.0 wt% yttrium, up to 0.06 wt% hafnium, up to 0.3 wt% silicon, 3-10 wt% tantalum, up to 5 wt% tungsten, 1-6 wt% rhenium, up to 10 wt% molybdenum, and a balance of nickel and any impurities.

Figure 3 illustrates another example component that is similar to the example shown in Figure 2 except that the component additionally includes a bond coat 44 that mitigates any thermal expansion mismatch between the material of the substrate 42 and the material of the barrier coating 40. For instance, the material of the bond coat 44 may be MCrAlY, where the M comprises at least one of nickel, cobalt, iron, or a combination thereof, Cr is chromium, Al is aluminum, and Y is yttrium. Alternatively, the bond coat 44 may be gamma-gamma prime nickel alloy or a nickel-based superalloy. The gamma-gamma prime nickel alloy may generally have a microstructure comprising nickel metal with phases of Ni₃(AlTi) dispersed throughout the nickel metal. One example nickel-based superalloy has a nominal composition of 22 wt.% cobalt, 17 wt.% chromium, 12.5 wt.% aluminum, 0.6 wt.% yttrium, 0.4 wt.% silicon, 0.25wt.% hafnium, and a balance of nickel and any impurities.

Although a combination of features is shown in the illustrated examples, not all of them need to be combined to realize the benefits of various embodiments of this disclosure. In other words, a system designed according to an embodiment of this disclosure will not necessarily include all of the features shown in any one of the Figures or all of the portions schematically shown in the Figures. Moreover, selected features of one example embodiment may be combined with selected features of other example embodiments.

The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those

skilled in the art that do not necessarily depart from the essence of this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

CLAIMS

1. A high temperature die casting system comprising:
a die casting tool having dies adapted for forming a component and being
5 operable to heat and maintain a temperature of the dies above 500°F/260°C, wherein
at least a portion of the die casting tool that is exposed for contact with molten die
casting material comprises a substrate and barrier coating on the substrate.
2. The high temperature die casting system as recited in claim 1, wherein the
10 barrier coating is alumina.
3. The high temperature die casting system as recited in claim 1, wherein the
barrier coating is silicon nitride.
- 15 4. The high temperature die casting system as recited in claim 1, wherein the
barrier coating is a refractory metal carbide.
5. The high temperature die casting system as recited in claim 4, wherein the
refractory metal carbide is hafnium carbide.
- 20 6. The high temperature die casting system as recited in claim 4, wherein the
refractory metal carbide is zirconium carbide.
7. The high temperature die casting system as recited in claim 4, wherein the
25 refractory metal carbide is selected from a group consisting of titanium carbide,
tungsten carbide, niobium carbide, tantalum carbide, rheniumcarbide,
molybdenumcarbide, siliconcarbide and combinations thereof.
8. The high temperature die casting system as recited in claim 1, wherein the
30 barrier coating is silicon-aluminum-oxy-nitride (SiAlON).

9. The high temperature die casting system as recited in claim 1, wherein the barrier coating is selected from a group consisting of boron nitride and aluminum nitride.
- 5 10. The high temperature die casting system as recited in claim 1, wherein the barrier coating is selected from a group consisting of gadolinia, zirconia, partially or fully stabilized zirconia material, and mixtures thereof.
- 10 11. The high temperature die casting system as recited in claim 1, wherein the barrier coating comprises at least one oxide and the balance comprising a first oxide selected from the group consisting of zirconia, ceria, and hafnia, the at least one oxide having a formula A_2O_3 where A is selected from a group consisting of La, Pr, Nd, Sm, Eu, Th, In, Sc, Y, Dy, Ho, Er, Tm, Yb, Lu, and mixtures thereof.
- 15 12. The high temperature die casting system as recited in claim 1, wherein the barrier coating includes a metallic coating selected from a group consisting of ruthenium, rhodium, palladium, osmium, iridium, platinum and combinations thereof.
- 20 13. The high temperature die casting system as recited in claim 1, wherein the barrier coating is a nickel alloy consisting essentially of up to 15 wt% cobalt, 5-18 wt% chromium, 7.5-12 wt% aluminum, 0.1-1.0 wt% yttrium, up to 0.06 wt% hafnium, up to 0.3 wt% silicon, 3-10 wt% tantalum, up to 5 wt% tungsten, 1-6 wt% rhenium, up to 10 wt% molybdenum, and a balance of nickel and any impurities.
- 25 14. The high temperature die casting system as recited in claim 1, further comprising a bond coat between the substrate and the barrier coating, and the bond coat is a material selected from a group consisting of MCrAlY, gamma-gamma prime nickel alloy, nickel-based superalloy, and combinations thereof.
- 30 15. The high temperature die casting system as recited in claim 1, wherein the substrate is a superalloy material.

16. A high temperature die casting system comprising:
a die casting tool including a substrate and barrier coating on the substrate,
wherein the barrier coating is a material selected from a group consisting of partially
or fully stabilized zirconia, titanium nitride, tungsten carbide, silicon carbide, silicon
5 nitride, titanium carbide, silicon-aluminum oxy nitride (SiAlON), hafnium carbide,
zirconium carbide, and combinations thereof.
17. The high temperature die casting system as recited in claim 16, wherein the
barrier coating is a partially or fully stabilized zirconia.
- 10 18. The high temperature die casting system as recited in claim 16, wherein the
barrier coating is silicon-aluminum-oxy-nitride (SiAlON).
19. The high temperature die casting system as recited in claim 16, wherein the
15 barrier coating is hafnium carbide.
20. The high temperature die casting system as recited in claim 16, wherein the
barrier coating is zirconium carbide.
- 20 21. A method for a high temperature die casting system, the method comprising:
maintaining a die casting tool having dies adapted for forming a component at
a temperature above 500°F/260°C; and
using a barrier coating on at least a portion of the die casting tool that is
exposed for contact with molten die casting material to protect an underlying substrate
25 of the die casting tool from the molten die casting material.